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Semiannual Report No. 2

Covering the Period August 15, 1973 through February 15, 1974

TECHNOLOGY TRANSFER—TRANSPORTATION

By: TOM ANYOS
RUTH LIZAK
JAMES WILHELM

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
TECHNOLOGY UTILIZATION OFFICE
NASA HEADQUARTERS
WASHINGTON, D.C. 20546

Attention: MR. RICHARD MINER
CODE KT

CONTRACT NASw-2455

STANFORD RESEARCH INSTITUTE
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SRI Project PYU-2201

Approved by:

MARION E. HILL, *Director*
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PREFACE

The NASA Technology Applications Team at SRI has been active in the technology transfer program since July 1, 1969. This is the second semiannual report under Contract NASw-2455; previous activities were covered under Contract NASw-1992. The overall objectives of the program are (1) to transfer aerospace technology to solving technological problems in public transportation, (2) to continuously refine and implement appropriate methods for ensuring successful transfers of technology in a reasonable amount of time, and (3) to provide visibility for program activities.

The members of the core team at SRI during this report period were:

Mr. Marion E. Hill, Program Supervisor
Dr. Tom Anyos, Program Director
Mr. James Wilhelm, Research Engineer
Mr. Kenneth Hirschberg, Research Engineer
Mrs. Ruth Lizak, Research Associate
Miss Patricia Pantell, Secretary

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INTRODUCTION

The National Aeronautics and Space Administration, Technology Utilization Office, established Technology Applications Teams (TAT) at several interdisciplinary research institutes to actively transfer aerospace technology to solve public sector problems. The teams match their problems with aerospace solutions by working with public sector representatives who can define the problems and NASA scientists and engineers who are knowledgeable of the applicable technology.

The SRI team has been operating for four and a half years and is currently concentrating on problems in the public transportation industry and refining methods for decreasing the time gap between the development and the marketing of new technology.

During this reporting period, eight NASA innovations were either being adapted for use on the highways, railways, or rapid transit, or were already entering the marketplace. Chronologies for three of these programs are provided in the following section. Brief descriptions of the others are given in Appendix A. Appendix B lists all SRI TAT technology transfers.

The team continued its efforts to maintain user confidence in the NASA technology transfer program. To this end, the team attempted to locate the barriers to the technology transfer process. A list of user agencies is provided in Appendix C.

Program visibility was provided by the team through an SRI TAT newsletter service, published quarterly, and a short article prepared for the APWA (American Public Works Association) Newsletter. The team assisted with program plans for a California Association of Criminalists seminar, and provided a display for the Third Urban Technology Conference. Further documentation is given in the section on program visibility in Appendix D.

PROBLEM/SOLUTION CHRONOLOGIES

Many interactions take place before a problem is matched with an aerospace solution and the solution is adapted to public use and to commercial production. It is not uncommon for dozens of contacts to be made between the user or users and TAT, the TAT and NASA scientists, the TAT and NASA Technology Utilization Officers, the user and NASA scientists, and the TAT and industry. On the following pages the SRI TAT has chronicled the principal interactions in three problems.

Restoration of Obliterated Serial Numbers

In cases of motor vehicle larceny, serial numbers stamped on the motor block are often obliterated (filed or ground off) so that legal ownership of the vehicle is difficult to determine. Restoration of these numbers is often necessary to prove the theft and convict the thief. Limited success has been achieved with currently used chemical and physical methods designed to achieve this restoration; however, none are really effective and all are very time-consuming.

In April 1971, the New York City Police Department contacted NASA to see if any NASA technology was available which would help solve this problem. The SRI team was informed of the problem and through a search of the literature in May 1971, learned of work being carried out at two NASA centers that appeared to relate to the problem. NASA-Marshall scientists suggested the use of liquid crystals in direct contact with the metal to restore the numbers, while NASA-Lewis workers suggested the use of ultrasonic cavitation techniques.

Contact was made with NASA during July to determine the feasibility of using these techniques for the restoration of serial numbers. The sensitivity of the crystals to the abraded surface was insufficient, however, restoration by ultrasonic cavitation (etching) showed promise.

A description of the technique was included in the team's Criminalistic Newsletter, No. 3, dated July 1971, and laboratories possessing ultrasonic equipment were asked for their evaluation. Considerable interest was expressed and at least one laboratory tried the technique. Due to the use of make-shift equipment not directly suited to the technique, the results were disappointing. The SRI team and the technique's developer, Mr. Stanley Young, agreed that a test program was needed to prove the applicability of the technique to restoring serial numbers.

In September 1971, the SRI team was asked to submit candidate adaptive engineering projects to NASA TU. Included in the 12 projects submitted by the team was the NASA-Lewis ultrasonic cavitation technique. Projects for TU were selected on the basis of the urgency of the need to achieve a transfer. In mid-November, the team learned that Mr. Young's test program would not be funded and another way would have to be found to carry out the program.

Discussions between the SRI team and Mr. Young continued into 1972. It was finally agreed that the test program would be conducted by Mr. Young as time permitted. To assist Mr. Young, in June 1972, the SRI team had numbers stamped into four metal blocks and then obliterated the numbers by grinding. (The four metals were copper, aluminum, brass, and steel.) The blocks were then sent to NASA-Lewis for restoration attempts.

From July 1972 until April 1973, Mr. Young experimented with the cavitation technique to restore the numbers. The technique restored all the numbers rapidly and efficiently, and eliminated the special sample handling required by other methods. The technique employs an ultrasonic vibrator (enclosed in a sound box) to generate very high frequency vibrations in water and create millions of microscopic bubbles. The bubbles impacted the metal blocks at thousands of pounds per square inch and dislodged the metal particles which are smeared into the stamped serial number grooves by grinding or filing. The numbers in aluminum and copper blocks were restored in 20 minutes, the numbers in brass were restored in 80 minutes, and it took 220 minutes for the numbers to be restored in the steel.

At the conclusion of the study, a NASA Technical Memorandum (NASA TM X-68257) was prepared for publication. A general rather than police-oriented approach was selected for the report. It was agreed, however, that a criminalistic version would be written for journal publication. Material on criminalistic/law enforcement was provided by the SRI team.

In May 1973, the team described the technique to the California Association of Criminalists (CAC). The CAC was favorably impressed and invited Mr. Young to present a paper at its 29th Semiannual Seminar.

The CAC meeting took place at SRI in Menlo Park, California, on October 17-19, 1973. Mr. Young described his technique and his test program, and showed slides of the cavitated metal specimens at various stages of restoration. Concurrent with his presentation, a press release on the technology and the application was issued by NASA. And in the November 5, 1973 issue of Chemical and Engineering News, the NASA technique was described in a newscript.

No further action has been taken although the team has learned that the State of California Crime Laboratories are investigating the utilization of the technique.

Roller Bearing Failure Detection

In mid-1972, the SRI team and the Association of American Railroads (AAR) discussed the importance of detecting the basic causes of roller bearing failure at an early stage. An incipient failure detection system would eliminate bearing-caused derailments and would allow for more effective maintenance scheduling.

For many years, the railroad industry used a trackside system to monitor the temperature of railcar journal bearings. A bolometer compared the temperatures of bearings on each side of an axle. If the temperature differential was greater than a specified preset limit, a hot box was indicated and corrective action was taken.

In 1968, however, the industry began incorporating roller bearings in all its new and rebuilt railcars. About one-half of the 2 million U.S. railcars are now equipped with roller bearings. Bolometers, which worked so well for journal bearings, cannot detect the incipient failure of roller bearings as these bearings do not exhibit the long temperature rise prior to failure that is characteristic of journal bearings.

The SRI team searched the NASA data base and uncovered the following Tech Brief, "Series-Hybrid Bearing: An Approach to Extending Bearing Fatigue Life at High Speeds," (B71-10173). A manual search conducted later produced two more Tech Briefs: "A System for Early Warning of Bearing Failure," (B72-10494) and "New Detection Method for Rolling Element and Bearing Defects," (B72-10689). All three briefs were in the hands of the AAR Roller Bearing Committee by January 1973.

Some Committee interest was excited by Tech Briefs 72-10689 and 72-10494, however, because the Committee is a test division (testing hardware, not concepts), the briefs were forwarded to the AAR's Roller Bearing Manufacturers' Engineers Committee.

During this same period, the SRI team established contact with Mechanical Technology, Inc., where the ultrasonic techniques (B72-10494 and B72-10689) were developed under a NASA contract. The latter technique is a further development of the earlier one. It was learned that Mr. Burchill and Mr. Frarey, the innovators, had left Mechanical Technology to set up their own company, Shaker Research, Ballston Lake, New York, to fabricate vibration and acoustic monitors. In September 1973, when the SRI team contacted Shaker to inform them of the AAR's interest in their technique, it learned that a prototype unit had already been built for testing automotive bearings.

An evaluation of the vibration measuring system was received from the Roller Bearing Manufacturers' Engineers Committee in early October 1973. Although the procedure performed well in the laboratory, the Committee felt it would not be satisfactory in the field due to extraneous noise. (Roll-by inspection was desired.)

The SRI team met with Shaker personnel on October 23, 1973 and repeated the comments made by the RBMEC. During the discussion, an adaptive engineering program was outlined for applying the rolling element defect detector to railcars. In Phase I, the key failure would be identified; a test configuration fabricated; roller, cage, and race faults induced to identify fault signatures; examples and level setting verified by used roller bearings; and a breadboard model built. Phase II would include the field testing and the instrument design. The program cost was estimated to be $20,000. On October 25, 1973, the proposed adaptive engineering program was described to the AAR by the SRI team.

During January and February 1974, Shaker Research Corporation began Phase I by building a laboratory unit for testing railcar roller bearings (see Figure 1). Adaption of the device for field use will await further word from the railroads, however. Shaker estimates that the market price for the proposed trackside device will be well under $500.

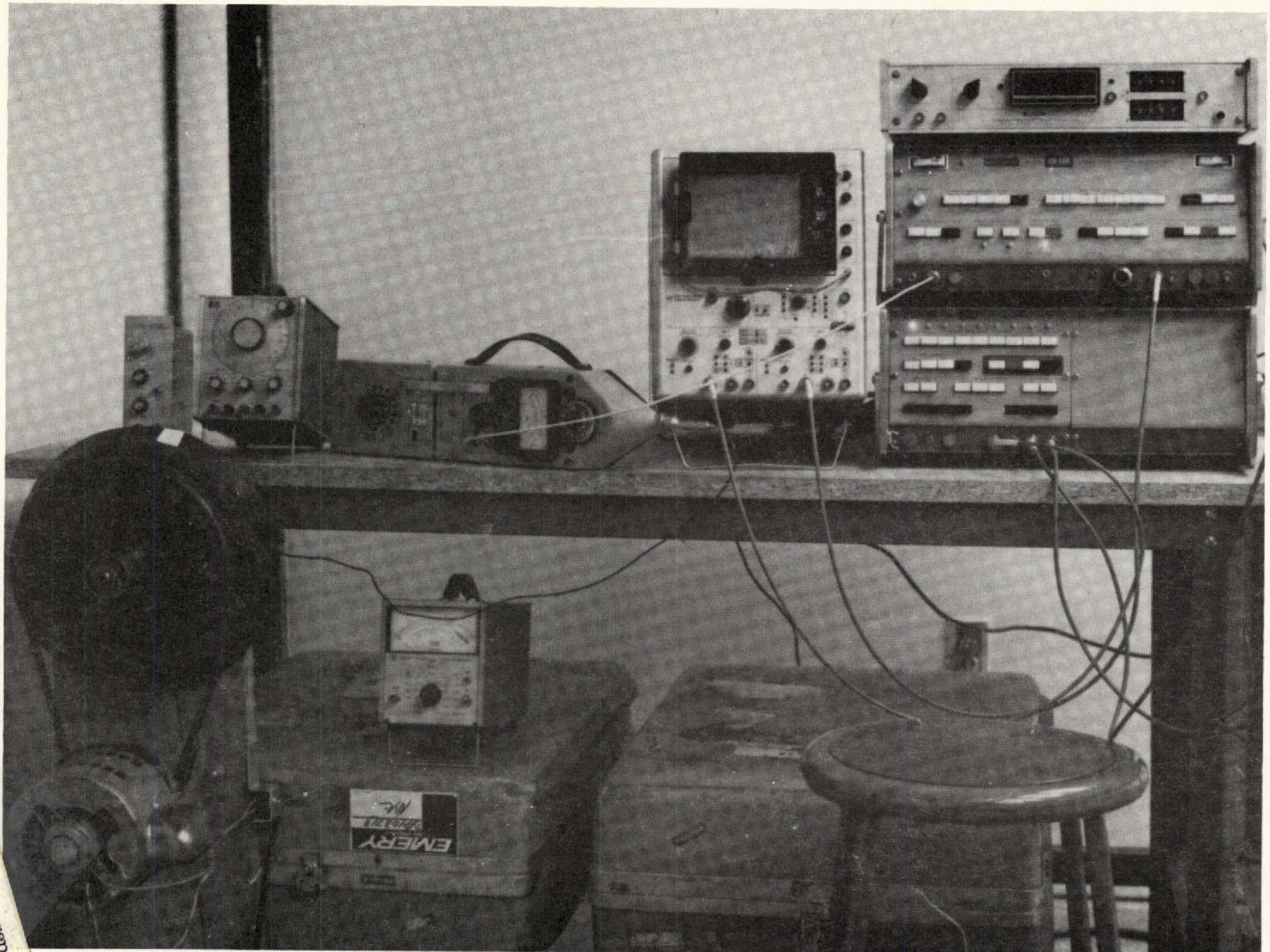

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FIGURE 1 LABORATORY SETUP FOR ROLLER BEARING DEFECT DETECTION

Electro-explosive Devices (EEDs) for Passenger Restraint Systems

During a visit to the Jet Propulsion Laboratory in September 1973, the SRI team learned of the possible over-sensitivity of explosive squibs used in passenger restraint airbag assemblies. If the squibs are too sensitive to extraneous radio frequency signals, the air bags could inflate unexpectedly, with possible disastrous consequences.

An estimated 50 to 80 million EEDs per model year (to provide for replacements, redundant circuits, and so forth) will be needed by 1976 by the automotive industry. Reliability values of individual explosive components of as high as 0.99999 would still allow potentially several hundred demand-fire or inadvertent-actuation failures each year.

Research has been under way for some time at JPL on explosive squibs of low-voltage capacitance and on the nondestructive testing of EEDs. A JPL EED is pictured in Figure 2. During the first half of 1972, three reports[(1)(2)(3)] were prepared for NASA on the relationship between the squib's bridgewire's response to pulsed current and the thermal behavior of the bridgewire-explosive interface. High reliability

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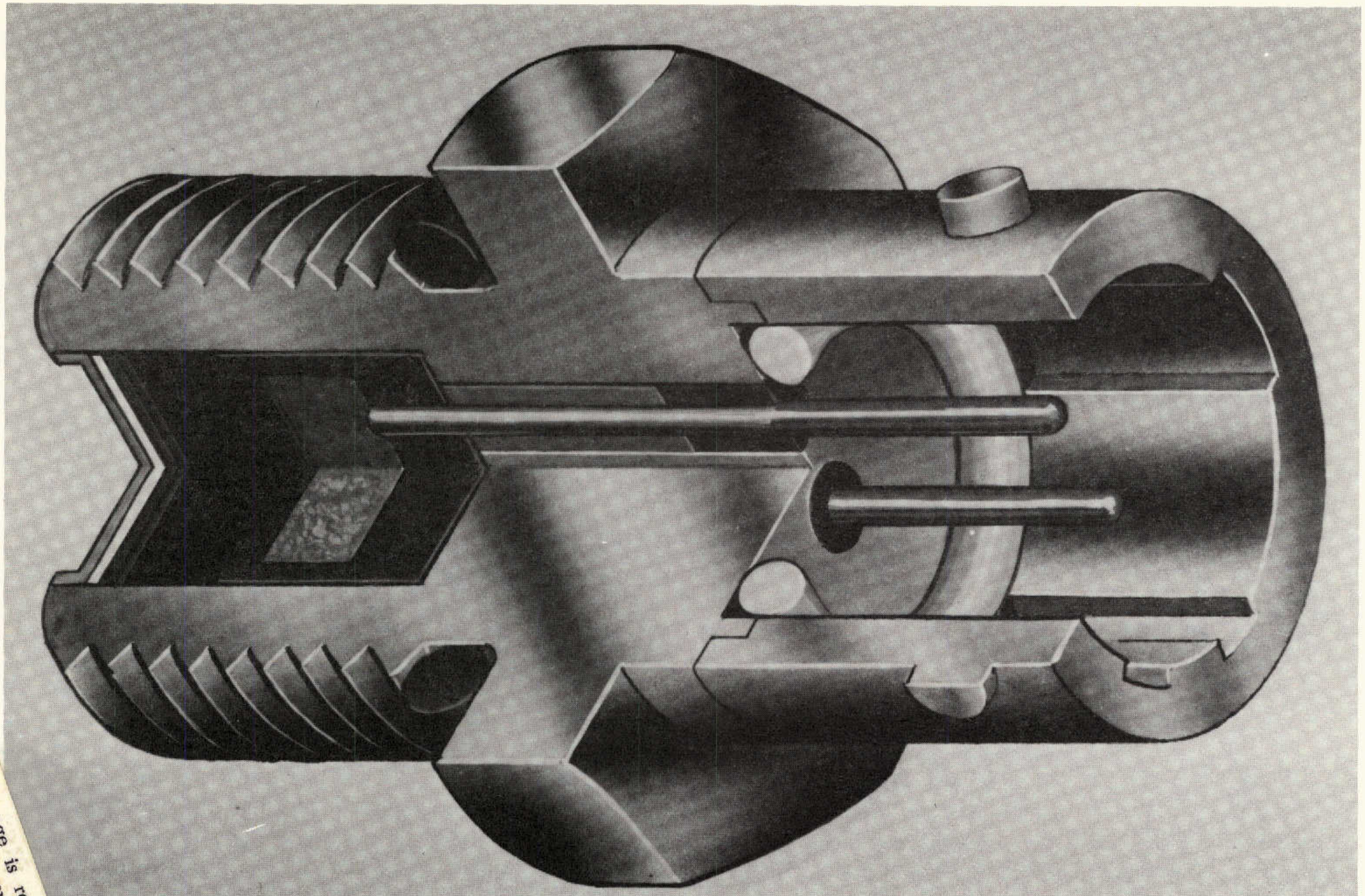
(1) Menichelli, V.J., and Rosenthal, L.A., "Fault Determinations in Electroexplosive Devices by Nondestructive Techniques," Jet Propulsion Laboratory, Pasadena, California, NASA Technical Report 32-1553, Contract NAS 7-100, March 15, 1972.

(2) Rosenthal, L.A., and Menichelli, V.J., "Electrothermal Follow Display Apparatus for Electroexplosive Device Testing," Jet Propulsion Laboratory, Pasadena, California, NASA Technical Report 32-1554, Contract NAS 7-100, March 15, 1972.

(3) Menichelli, V.J., "Evaluation of Electroexplosive Devices by Nondestructive Test Techniques and Impulsive Waveform Firings," Jet Propulsion Laboratory, Pasadena, California, NASA Technical Report 32-1556, Contract NAS 7-100, June 15, 1972.



SA-2201-19

FIGURE 2 SQUIBS FOR ELECTRO-EXPLOSIVE DEVICES

EEDs are essential aboard spacecraft because many critical functions are explosively actuated.

In October 1973, the TAT contacted representatives of the U.S. Department of Transportation and asked about their interest in the air bag-squib problem. The problem concerned them, and they were anxious to learn more about the work at JPL.

At the TAT's suggestion, a research plan was prepared at JPL for evaluating the use of EEDs in passive restraint systems. The ignition aspects (both capacitor discharge power supplies and the battery energy) of proposed and current airbags would be suited: This study would be to determine whether current designs would preclude inadvertent actuation. The study would establish a set of design criteria and recommended standard practices for the design, manufacture, quality control, and maintainability of EEDs.

The writeup was first reviewed at DoT and then at the National Highway Traffic Safety Administration (NHTSA). Another copy was sent to the Vehicle Research Institute in Detroit, because JPL felt the study should be funded jointly by government and industry.

In November 1973, the TAT learned that the NHTSA contracts officer desired a financial commitment from NASA. Therefore, a proposal was prepared by JPL and submitted to NASA TU. Funding for this effort, if approved, would begin in FY '75.

PROGRAM VISIBILITY

To provide visibility for the NASA TU program, the SRI team initiated a newsletter service, provided material for an article in an association publication, and assisted with one technical meeting and participated in another.

The first issue of Technology Applications Notes, the SRI team newsletter, was published in September 1973. This quarterly publication documents recently uncovered NASA solutions to transportation problems. During the report period, two issues (reprinted in Appendix C) were circulated to approximately 80 user/potential-user agencies. In addition, the Institute for Transportation of the American Public Works Association carried an article that described the SRI team and encouraged readers to participate in the program. As a result of contacts with the SRI team, the Transit Development Corporation had this to say in its statement of work to the Urban Mass Transportation Administration: "Maximum advantage will be taken of technological work by NASA...that can be applied usefully toward elimination of safety hazards peculiar to a rail transit environment."

As is mentioned in the chronology on the Restoration of Obliterated Serial Numbers, the SRI team arranged for a paper on NASA's ultrasonic cavitation technique to be included at the 29th Semiannual Seminar of the California Association of Criminalists. The seminar was held at SRI in Menlo Park, California, on October 17-19, 1973.

Earlier in the report period, the team participated in the Third Urban Technology Conference. A display of SRI technology transfer was set up at the NASA both (Figure 3) and copies of a bibliography on

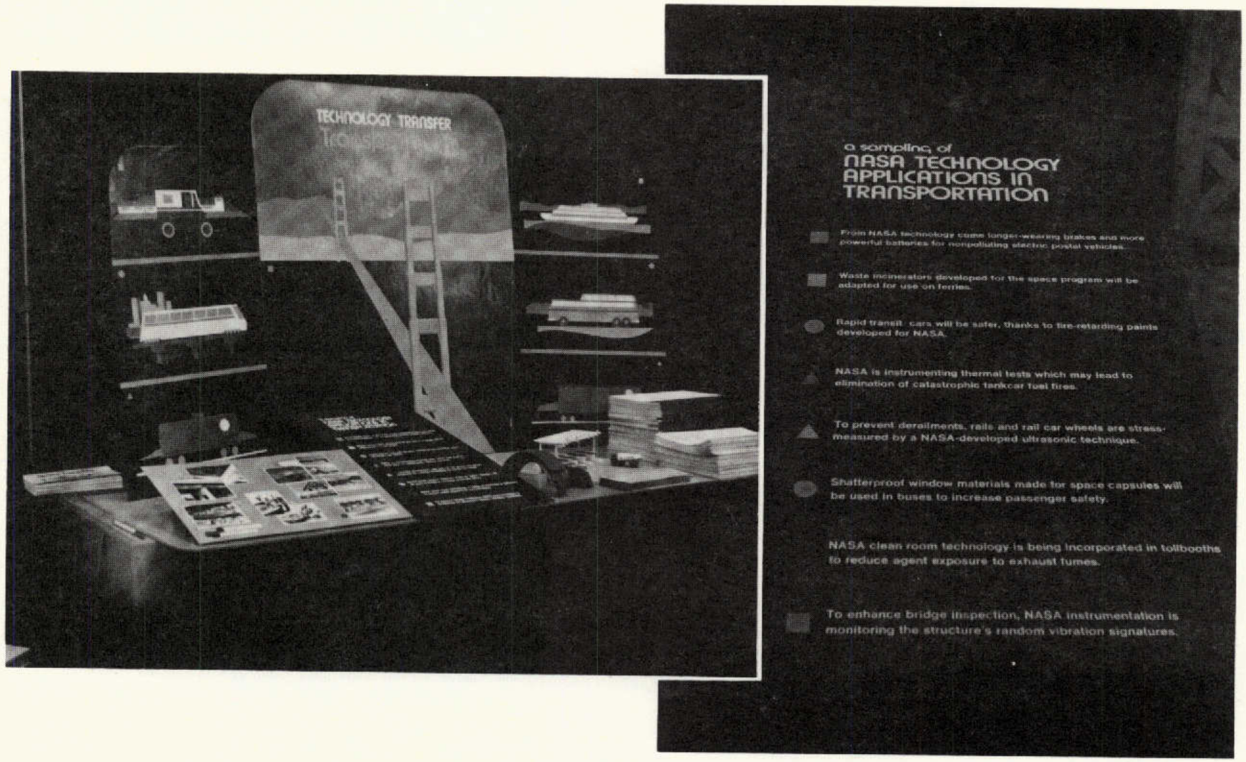


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FIGURE 3 SRI TAT DISPLAY AT THE THIRD URBAN TECHNOLOGY CONFERENCE rapid transit technologies* were handed out. Team members answered questions on the display technologies and on the role of the Technology Applications Teams. Program emphasis for the conference, which was held in Boston, Massachusetts on September 26-28, 1973, was on urban mass transportation and environmental protection.

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*Henderson, Clark, and Erickson, Linda, "Personal and Group Rapid Transit Systems and Technologies: A Selected Bibliography," SRI, Menlo Park, California, for Contract NASw-2455, May 1973.

CONCLUSIONS

During this report period, the SRI team has continued its efforts to decrease the time between problem identification and technology implementation. From the three chronologies provided in the previous section, one can see how quickly the technology is transferred, once an adaptive engineering program is undertaken. In the case of the obliterated serial numbers, only one month was required to find a potential solution to the problem, and only nine months for adapting and testing the solution. However, fourteen months elapsed before the adaptive engineering project got under way. A system to monitor railcar roller bearings was located six months after the problem was reactivated, whereas fourteen months were required to initiate the adaptive engineering. A JPL study plan on evaluating electro-explosive devices (EEDs) for air bag use has been under consideration by several agencies for five months and is still being reviewed. In each case, the transfer process slowed markedly when it reached the adaptive engineering phase.

The TAT has continued its efforts to identify relevant, readily transferrable NASA technology in the most expeditious manner and to effectively bridge the gap between public and private sector agencies.

Appendix A

TECHNOLOGY TRANSFERS

TECHNOLOGY TRANSFERS RESULTING FROM SRI/TAT ACTIVITY

- H-1 Driver Coordination
  LRC Complex Coordinator (B70-10619)
- H-2 Pavement Thickness Measurement
  MSFC Eddy Current Proximity Gage (B68-10183)
- H-5 Bridge Failure Detection
  ARC Randomdec Technique (B71-10284)
- H-6 Road Repair Material
  JPL Thermoplastic Material (B66-10453)
- H-8 Improved Friction Material
  ARC Polyphenylene Polymer
- H-16 Air Purification of Tollbooths
  NASA Air Diffuser (SP-5045, N66-11215)
- H-16 Restoration of Obliterated Serial Numbers
  LeRC Ultrasonic Cavitation (TB71-10099)
- R-2 Stress Measurement in Rails and Wheels
  MSFC Ultrasonics (B67-10428)
- R-3 Shock/Vibration Monitor
  LRC/AEC Triaxial Bidirectional Integrating
  4-Level Acceleration Amplitude Recorder
  (TB 71-10126 and UCRL 72748)
- R-5 Tank Car Thermal Protection Testing
  ARC Instrumentation for Tank Car Burn
- R-6 Track/Train Dynamics Projects
  MSFC Telemetry Assistance

INFORMATIONAL TRANSFERS
INSTIGATED BY THE SRI TAT

- Use of SRI TAT report on blood-alcohol levels in a training program for state criminalists.
- Kennedy Space Center assistance in analyzing Florida's films on water penetration.

Appendix B

CURRENT PROBLEMS, PROJECTS, AND TRANSFERS

ABSTRACTS OF PROBLEMS, PROJECTS, AND TRANSFERS

HIGHWAYS

**H-3 Pavement Texture Measurement: Highway-accident researchers have identified significant relationships between road surface texture characteristics and skid-related accident rates. As a result, the Federal Highway Safety Act of 1966 provided for "pavement design and construction with specific provisions for high skid-resistance qualities" and "resurfacing or other surface treatment...of streets and highways with low skid resistance...." The surface texture of highway pavements must be measured to determine skid potential. The test device (preferably an electronic instrument) should be operable at maximum highway speeds. A study was conducted at NASA's Langley Research Center to relate road texture to skid. A NASA Technical Memorandum covering the study has been prepared and will be available soon.

*H-5 Bridge Failure Detection: Technology is sought to enhance bridge inspection capability. There are approximately 500,000 bridges on U.S. highways, and no definitive method exists for determining which ones may be in jeopardy due to cracks not detectable by routine visual inspection. The SRI Team learned of a NASA-Ames technique, called Randomdec, that monitors the structure's random vibration signatures. It uses accelerometers as sensors, which feed into a correlation computer. A joint NASA/FHWA project (involving an interagency transfer of funds from FHWA to NASA) is being undertaken by the innovators to evaluate the technique in laboratory and field tests. The program will now be administered by NASA-Ames, with the SRI TAT moving into the follow-on stages.

*Transfer Phase

**Project Phase

*H-6 Road Repair Material: Highway maintenance crews desired a strong patching material that could be applied and set between rush hours, when closing a lane would not impede the flow of traffic. A thermoplastic material that was developed at NASA's Jet Propulsion Laboratory as a rocket propellant binder appeared to fill this need. A formulation of the material, with a safe-handling melting point, was mixed with aggregate and applied by the California Division of Highways to the deceleration lane of California Highway 99 at Florin Road. After almost 2 years, the test strip that had been applied with heated aggregate had 100% aggregate retention. At the suggestion of the CDH, the material is being included in the National Cooperative Highway Research Program's chip seal tests. The formulation was prepared for NCHRP by Matrecon, Inc. and installed on Matrecon's test track.

Representatives of the SRI TAT and Public Technology, Inc. (PTI) visited a chemical company in southern California, Products Research and Chemicals Corporation (PRC), to discuss commercialization of the thermoplastic material. A cooperative effort was initiated by PTI and the producer, with SRI moving into the follow-on stages.

Tests on the PRC material continue. A second generation "cold mix" material has evolved which shows considerable potential for patching operations.

H-7 Pavement Delineation: Current road marking systems are not fully acceptable because they are slow drying, have limited durability, lose their effectiveness under wet or foggy conditions, or are susceptible to damage by snowplows. All systems are costly. New concepts for marking or improved materials are greatly needed.

*H-8 Improved Friction Material: New materials for brake linings are greatly needed for increased wear and safety. The Postal Service is anxious to increase the time between relinings for postal vehicles. The Postal Service, the railroad industry, and others are interested in a brake lining that does not contain asbestos, a material suspected of being a public health hazard. An improved material was found at NASA-Ames in a reformulated airplane friction material developed for SST brakes. A production economics study made at SRI indicated that the new composition can be produced at a reasonable cost. Therefore, an adaptive engineering program was undertaken at Ames to modify the material for postal vehicle use. Brake linings are currently being fabricated at Bendix Corporation from the Ames material.

*Transfer Phase

**H-9 Electric Vehicle: The Postal Service is considering electric vehicles for mail delivery. Although long-range plans include a fuel cell concept for supplying power, an improved battery would provide a good short-range solution. Currently available lead-acid batteries supply 10 to 15 watt-hr/lb, whereas at least 30 watt-hr/lb are necessary to accelerate from 0 to 45 mph in 45 seconds during transit and from 0 to 10 mph in 3 seconds during mail delivery. As many as 130 stops may be required on one route, 35% on uphill grades. To take full advantage of battery improvements, a more efficient electric motor is also being sought, one requiring little maintenance.

Work is under way at NASA-Lewis to design a high performance battery which in laboratory tests on small cells is achieving very close to 30 watt-hr/lb.

H-10 Subsurface Moisture Measurement: The negative relationship between the presence of water and the service life of a pavement has been recognized for a long time by highway engineers. Efforts to remove subsurface moisture have been hampered, however, by the lack of accurate instruments or techniques for measuring moisture. Instrumentation is desired that can be implanted in pavement or subgrade and can provide a readout of local moisture content on demand. The device should be long-lasting, small, durable, and inexpensive because many may be needed in suspect areas.

H-11 Examination of Sinkhole-Prone Areas: In addition to the usual structural inspection of bridges, Florida will be required to test the foundations for sinkholes. Since almost all of Florida's 5000 highway bridges are located in areas prone to sinkholes, an inspection method is desired requiring little or no drilling, which is time-consuming.

H-15 Bridge Corrosion: Because of their exposure to salt spray, coastal bridges require more corrosion protection than is needed inland. Currently available zinc coatings provide only a few years of coastal protection, whereas coatings on inland bridges provide protection over a fifteen-year period.

**Project Phase

H-19 Vehicle Velocity Measurement: The Texas Department of Highways is looking for instrumentation to measure and record the rate of deceleration of vehicles on grades. Instrumentation must also identify the vehicles (e.g., holography, photography, or classification by weight) if the speed measurements are to be meaninfgul. The resulting data will be analyzed for use in highway design.

**H-20 Electro-Explosive Devices (EEDs) for Passenger Restraint Systems: The air bag system, a proposed solution to the Department of Transportation (DoT) requirement for automobile passenger passive restraint capability for 1976 models, may introduce potentially hazardous and operationally unreliable side effects.

Inflation of individual air bags will be controlled by a bumper-mounted deceleration sensor which, upon sensing deceleration indicative of a crash mode, signals the electro-explosive device to inflate the bag. Inadvertant system initiation and failure to achieve system initiation are significant possibilities. A proposed study to alleviate this danger has been suggested by JPL to the DoT, Society of Automotive Engineers (SAE) and Vehicle Research Institute (VRI). The TAT, in coordination with JPL has brought this study to the attention of the National Highway Traffic Safety Administration (NHTSA) and will coordinate future cooperative efforts.

H-21 Cableless Buried Sensors: Cableless sensors are needed for monitoring earth movement and pressure in embankments to prevent landslides. A remote sensing technique is being sought because leadout wires are often broken, leaving the sensors useless. Flexible cable and conduits have been tried without much success.

RAILWAYS

**R-1 Roller Bearing Failure Detection: The railroad industry is currently changing over from journal bearings to roller bearings, which give better service. Journal bearings are monitored for impending failure by bolometers, which compare the temperatures of bearings on either side of the axle. This method is not effective for roller

**Project Phase

bearings, however, because they do not exhibit the long temperature rise before failure that is characteristic of journal bearings.

A vibration measuring technique for use on automotive vehicles was uncovered in NASA Tech Brief 72-10689. The technique is currently being adapted for railcar bearings at Shaker Research Corp.

*R-2 Stress Measurement in Rails and Wheels: Detection of locked-in stresses is essential in preventing derailments. In rails, these stresses are caused by maintenance work done at different times and at different temperatures; in wheels, they are caused by friction braking. NASA-Marshall has developed ultrasonic techniques for measuring stress conditions near welds in large assemblies. The SRI Team arranged a meeting at Marshall to demonstrate the feasibility of applying these techniques to the measurement of stress in rail and wheel rim segments. The segments were supplied by the Association of American Railroads. Feasibility was successfully demonstrated, and additional work at Marshall was funded by the Federal Railroad Administration.

Ultrasonic velocity measurements were made on assorted wheel segments, calibration blocks and five wheels. Repeated measurements on a given sample were consistent; however, considerable material variability was found. Stress change measurements may be possible by measuring the initial conditions of wheels as a reference for future measurements. Development of a method to evaluate material variability would eliminate the need for such a procedure.

*R-4 Thermal Coating for Tank Cars: The railroad industry is studying ways to prevent catastrophic failures of tank cars in post-derailment environments. Fire retardant or protective coatings are being evaluated for their ability to maintain 5/8-inch-steel tank cars at 800° or below for 1/2 to 4 hours during a fire. The SRI Team found a potential candidate material in a fiber-loaded intumescent coating developed at NASA-Ames. The material has been submitted to the Association of American Railroads for evaluation.

*R-5 Tank Car Thermal Protection Testing: NASA-Ames researchers working on thermal coatings for tank cars pointed out differences between the AAR/RPI fire test and other laboratory tests for

*Transfer Phase

simulating large pool fires. This led to a request by AAR/RPI for assistance from NASA in simulating a full-scale tank car fire and developing a suitable laboratory qualifying test procedure for candidate coatings. A proposal for a program to establish a qualifying procedure was submitted by the Chemical Research Projects Office at Ames, was approved by the AAR/RPI, and was funded by the Federal Railroad Administration. The test program subjected instrumented tank cars to actual fuel fires. As a result of the FRA program, two test facilities will be constructed at NASA-Ames, one for pool fires and the other for torch fires.

R-12 Air Brake Hose: Burst air-brake hoses cause too many railroad delays. When a freight train is formed, each railcar air brake system is joined to the systems of adjacent cars by air brake hose couplings, and the entire braking system is pressurized to 90 psi. A failsafe system causes each car's brakes to be automatically applied whenever a certain reduction in pressure occurs. Because burst hoses cause pressure drops which stop trains, improved hoses are being sought.

R-13 dc Motors: An untold number of transit cars operate in the United States, and the dc motor is the main propulsion unit on many of them. In New York City alone, 30,000 motors are in operation daily. Frequent maintenance and replacement of these motors are required, however, due to arcing, flashovers, burnups, and dc commutation problems. Better motors are needed to reduce maintenance costs.

R-14 High-Temperature Lubricants: Two aspects of the lubricant problem are recognized: performance under thermal conditions and resistance to fire. Railroad and rapid transit agencies are considering both aspects, and are also investigating test methods. At the AAR, an ad hoc committee has been formed to conduct the investigation.

R-15 Bridge Surveillance: The railroads are forced to absorb large repair costs for bridge damage from unreported barge collisions. To enable the railroads to claim damages, a surveillance system (e.g., low light-level photography) is needed to identify the culprits.

URBAN MASS TRANSIT

U-1 Shatterproof Windows: From the standpoint of maintenance and repair, bus windows are a major concern of bus operators. Broken windows from rocks thrown at passing buses and from road debris represent both a safety hazard and an economic burden to the bus operator. The need for shatterproof, optically clear materials for use in bus windows has therefore been demonstrated. Although materials are currently available that claim to meet this need, none has proven totally acceptable.

U-2 Acoustic Material: Noise levels currently reached in subway tunnels are as much as 20 to 30 decibels above requirements specified by new systems under construction. Wheel/rail, mechanical equipment, and electrical contact rail noise propagates and is reflected by the tunnel enclosure into the passenger vehicle interior, sometimes at objectionable levels. Since most of the noise originates at the level of the undercarriage, acoustic treatment at the lower level of the tunnel is critical. The presence of contaminents in this area, such as grease, oil, water, and brake shoe dust, call for a low maintenance lining. A spray-on, asbestos-free, cementitious material, easily applied to concrete and metal surfaces, would be useful.

U-3 Smokeless Nontoxic Cables: Fires in subway tunnels have resulted in considerable property damage as well as deaths and injury to the public involved. The blinding smoke and toxic gas evolved in a fire in such a confined area can be a greater threat to passengers than the fire itself. Much of this problem could be eliminated if a smokeless, nontoxic gas producing coating or covering could be applied to existing signal, communication, and traction power cables in tunnels. Most cables have a neoprene cover and a butch jecket, but the splice chambers are the main locations requiring cover.

WATERWAYS

W-1 Waste Disposal: Environmental regulations forbid the off-shore dumping of sewage. Therefore, a self-contained sewage processor is needed for Alaska's long-haul ferries which are at sea for several days between stops. The ferries carry up to 200 passengers.

Appendix C

CURRENT USER AGENCIES

CURRENT USER AGENCIES

Alaska Department of Highways,
Juneau, Alaska

Alaska Department of Public Works,
Juneau, Alaska

American Public Works Association,
Chicago, Illinois

American Transit Association,
Washington, D.C.

Arizona State Division of Highways,
Phoenix, Arizona

Atcheson, Topeka, and Santa Fe
Railway,
Chicago, Illinois

Bay Area Rapid Transit District,
Oakland, California

Burlington Northern, Inc.,
St. Paul, Minnesota

California Department of Justice,
Sacramento, California

California Department of
Transportation,
Sacramento, California

Chicago Transit Authority,
Chicago, Illinois

Cleveland Transit System,
Cleveland, Ohio

Colorado Division of Highways,
Denver, Colorado

Dallas/Fort Worth Airport,
Irving Texas

D.C. Department of Transportation,
Washington, D.C.

Federal Highway Administration,
Washington, D.C.

Federal Railroad Administration,
Washington, D.C.

Florida Department of Transportation,
Tallahassee, Florida

Idaho Department of Highways,
Boise, Idaho

Indiana State Highway Commission,
Indianapolis, Indiana

Long Island Rail Road,
Jamaica, New York

County of Los Alamos,
Los Alamos, New Mexico

Los Angeles County Road Department,
Los Angeles, California

Maryland Department of Transportation,
Brooklandville, Maryland

Mass Transit Administration,
Baltimore, Maryland

Massachusetts Bay Transportation Authority, Everett, Massachusetts

Metropolitan Atlanta Rapid Transit Authority, Atlanta, Georgia

National Association of Motor Bus Operators, Washington, D.C.

Nevada State Department of Highways, Carson City, Nevada

New York City Transit Authority, Brooklyn, New York

Ohio Highway Transportation Research Center, East Liberty, Ohio

Oregon Department of Transportation, Salem, Oregon

Pennsylvania Department of Transportation, Harrisburg, Pennsylvania

Port Authority Trans-Hudson Corporation, New York, New York

St. Louis-San Francisco Railway Company, Springfield, Missouri

Southeastern Pennsylvania Transportation Authority, Philadelphia, Pennsylvania

Southern California Rapid Transit District, Los Angeles, California

Southern Pacific Transportation Company, San Francisco, California

Southern Railway System, Alexandria, Virginia

Texas Department of Highways, Austin, Texas

Transit Development Corporation, Inc., Washington, D.C.

Transportation Systems Center, Cambridge, Massachusetts

Union-Pacific Railroad, Omaha, Nebraska

United States Postal Service, Rockville, Maryland

Urban Mass Transportation Administration, Washington, D.C.

Utah State Highway Department, Salt Lake City, Utah

Washington Department of Highways, Olympia, Washington

Washington Metropolitan Area Transit Authority, Washington, D.C.

Appendix D

PUBLICATIONS

INSTITUTE FOR TRANSPORTATION
of the AMERICAN PUBLIC WORKS ASSOCIATION

NEWSLETTER

Vol. 1 / Number 3 Fall 1973

NASA TO SHARE INFO

The National Aeronautics and Space Administration's Technology Utilization Office hopes to transfer technology gained from the US aerospace program to other areas. One aspect matches public agency problems with solutions in the aerospace knowledge bank. A Technology Applications Team (TAT) performs this function at inter-disciplinary research institutes, with public-sector representatives and NASA scientists and engineers.

At Stanford Research Institute, a NASA team is working to help solve transportation problems. Coupled with this mission is the development and application of methodology to achieve such transfer, particularly in ways to decrease the time gap between the development and marketing of new technology. For further information, contact Dr. Tom Anyors, Director, Technology Applications Team, Stanford Research Institute, Menlo Park, Calif. 94025.

TECHNOLOGY APPLICATIONS NOTES

NASA Technology Applications Team
Stanford Research Institute
Menlo Park, California 94025

Number 1 September 1973

An active effort is being made by the National Aeronautics and Space Administration's Technology Utilization Office to transfer technology from the US aerospace program. One aspect of this effort matches problems in the public sector with solutions in the aerospace knowledge bank. A Technology Applications Team (TAT) performs this function at several interdisciplinary research institutes, interacting (a) with public-sector people who can define the problems and (b) with NASA scientists and engineers who can bring technology to bear on the problems.

One such activity takes place at Stanford Research Institute (SRI) where a NASA sponsored team has operated for more than four years. Its primary objective is in the transfer of technology from the aerospace bank to help solve problems in the many fields of transportation. Coupled with this mission is the development and application of methodology to achieve such transfer, particularly in ways to decrease the time gap between the development and marketing of new technology. In this way, the TAT is able to aid the movement of knowledge across industrial, disciplinary, and regional boundaries.

The TAT's transportation activities has brought about interaction in the Highways, Railways, Rapid Transit and Mass Transit, and Waterways areas. It is the purpose of these Technology Applications Notes to inform you of some of the team's current activities, problem areas under investigation and recent solutions. Your comments, questions, problems, and requests for further information are invited.

HIGHWAYS

Pavement Thickness Measurement: In both newly laid and older Portland cement concrete pavements, it is necessary to determine the thickness with some degree of accuracy. For new pavement, measurement is necessary to ensure that construction specifications have been met. For older pavement, load carrying capabilities must be assessed. Because of the miles of highway to be tested and the close spacing of the tests, a rapid, inexpensive method is needed--preferably a nondestructive one.

A battery-operated proximity gage was developed at Marshall Space Flight Center. Similar to a metal detector, it can detect a metal plate or foil laid on the base course before paving with a ± 0.1-in accuracy.

The device was successfully tested in Pennsylvania and Louisiana. A final design has now been approved for marketing, and South Eastern Associates of Huntsville, Alabama is beginning production.

Bridge Failure Detection: Technology is sought to enhance bridge inspection capability. There are approximately 500,000 bridges on U.S. highways, and no definitive method exists for determining which ones may be in jeopardy due to cracks not detectable by routine visual inspection. The SRI Team learned of a NASA-Ames technique, called Randomdec, that monitors the structure's random vibration signatures. It uses accelerometers as sensors, which feed into a correlation computer. A joint NASA/FHWA project (involving an interagency transfer of funds from FHWA to NASA) is being undertaken by the innovators to evaluate the technique in laboratory and field tests. The program will now be administered by NASA-Ames, with the SRI TAT moving into the follow-on stages.

Examination of Sinkhole-Prone Areas: In addition to the usual structural inspection of bridges, Florida will be required to test the foundations for sinkholes. Since almost all of Florida's 5000 highway bridges are located in areas prone to sinkholes, an inspection method is desired requiring little or no drilling, which is time-consuming.

Interest has been expressed by Florida and several other southeastern states in NASA's swept-frequency UHF radiometer (B70-10617) developed for probing the lunar surface. Plans are being made for initiating a feasibility study.

Subsurface Moisture Measurement: The negative relationship between the presence of water and the service life of a pavement has been recognized for a long time by highway engineers. Efforts to remove subsurface moisture have been hampered, however, by the lack of accurate instruments or techniques for measuring moisture. Instrumentation is desired that can be implanted in pavement or subgrade and can provide a readout of local moisture content on demand. The device should be long lasting, small, durable, and inexpensive because many may be needed in suspect areas.

In this case, as with examination of sinkhole-prone areas, the NASA swept-frequency radiometer appears to be feasible for initial trials. Such trials are currently being scheduled.

Stress Measurement in Rails and Wheels: Detection of locked-in stresses is essential in preventing derailments. In rails, these stresses are caused by maintenance work done at different times and at different temperatures; in wheels, they are caused by friction braking. NASA-Marshall has developed ultrasonic techniques for measuring stress conditions near welds in large assemblies. The SRI Team arranged a meeting at Marshall to demonstrate the feasibility of applying these techniques to the measurement of stress in rail and wheel rim segments. The segments were supplied by the Association of American Railroads. Feasibility was successfully demonstrated, and additional work at Marshall was funded by the Federal Railroad Administration.

Ultrasonic velocity measurements were made on assorted wheel segments, calibration blocks and five wheels. Repeated measurements on a given sample were very consistent; however, considerable material variability was found. Stress change measurements may be possible by measuring the initial conditions of wheels as a reference for future measurements. Development of a method is under way to evaluate material variability to eliminate the need for such a procedure.

Tank Car Thermal Protection Testing: NASA-Ames researchers working on thermal coatings for tank cars pointed out differences between the AAR/RPI fire test and other laboratory tests for simulating large pool fires. This led to a request by AAR/RPI for assistance from NASA in simulating a full-scale tank car fire and developing a suitable laboratory qualifying test procedure for candidate coatings. A proposal for a program to establish a qualifying procedure was submitted by the Chemical Research Projects Office at Ames and was approved by the AAR/RPI and the SRI Team. It has been funded by the Federal Railroad Administration. The test program in which instrumented tank cars are subjected to actual fuel fires is currently under way.

Thermal Coating for Tank Cars: The railroad industry is studying ways to prevent catastrophic failures of tank cars in post-derailment environments. Fire retardant or protective coatings are being evaluated for their ability to maintain 5/8-inch-steel tank cars at 800° or below for 1/2 to 4 hours during a fire. The SRI Team found a potential candidate material in a fiber-loaded intumescent coating developed at NASA-Ames. Over forty samples, including the Ames material, were evaluated by the Association of

American Railroads. The Ames coating was one of several meeting the time-temperature specifications, but apparently was the only one meeting the specifications for strength, weatherability, and ease of application. Its cost was the main drawback to the material's acceptance. The formulation was modified to reduce the cost and application time. In addition, an appropriate outer coating to allow color variation was identified at the Naval Air Development Center at Warminster, Pennsylvania. The foam is now being produced commercially.

Track/Train Dynamics Projects: The Association of American Railroads is embarking on a national research program to investigate Track/Train Dynamics. The program is expected to lead to improved operating procedures and equipment design. The AAR and the Federal Railroad Administration, a partial sponsor of the program, wish to benefit from some of NASA's unique technology and capability in data acquisition and analysis, instrument development, and dynamic modeling. Therefore, NASA-Marshall assistance on the program has been contracted.

For additional information on any of these problem areas, please contact the Team members listed below. If your problem areas differ from those listed here, we invite you to discuss them with us. The TAT's activities are only partially represented here. Interaction on numerous other highway, rail, rapid transit and waterways problems is constantly under way. It is indeed possible that we may have already considered the problem you are facing, and may have uncovered a solution for it. We look forward to hearing from you.

Dr. Tom Anyos, Director
Mrs. Ruth Lizak, Team Leader, Highways
Mr. James Wilhelm, Team Leader, Rapid Transit
Mr. Kenneth Hirschberg, Team Leader, Railways

TECHNOLOGY APPLICATIONS NOTES

NASA Technology Applications Team
Stanford Research Institute
Menlo Park, California 94025

Number 2 November 1973

This issue is the second in a continuing series of Notes by the NASA-sponsored Technology Applications Team at Stanford Research Institute (SRI). Each issue documents recently uncovered NASA solutions to some transportation (highway, railway, rapid and mass transit, and marine) problems. Comments, questions, and requests for further information are always welcome.

Also included in these Notes are descriptions of a few problems that are currently being investigated by the Team. Any interest in these or other problems should be brought to the attention of one of the Team members.

HIGHWAYS

Improved Friction Material: New materials for brake linings are greatly needed by trucks, buses, and postal vehicles to increase wear and safety. One such material was found at NASA-Ames in a reformulated airplane friction material developed for SST brakes. A production economics study made at SRI indicated that a new composition could be produced at a reasonable cost. Therefore an adaptive engineering program was undertaken at NASA-Ames to modify the material for highway use. From this modified material, experimental brake linings are now being developed at Bendix Corporation preparatory to road testing.

Restoration of Obliterated Serial Numbers: Serial numbers stamped in motor blocks are often filed off in an attempt to change the identification. A means of retrieving the original numbers was developed at NASA-Lewis by ultrasonically induced cavitation (NASA Tech Brief 71-10099).

Specimens of copper, brass, steel, and aluminum were stamped at SRI and then obliterated by grinding. At NASA-Lewis, cavitation in water was induced by the ultrasonic vibration of a piezoelectric transducer. The numbers were restored. The restoration procedure is documented in NASA report TM-X-68257.

Roller Bearing Failure Detection: The railroad industry is currently changing over from journal bearings to roller bearings, which give better service. Journal bearings are monitored for impending failure by bolometers, which compare the temperatures of bearings on either side of the axle. This method is not effective for roller bearings, however, because they do not exhibit the long temperature rise before failure that is characteristic of journal bearings.

The Team uncovered a very promising solution to the bearing problem, NASA Tech Brief 72-10689, "New Detection Method for Rolling Element and Bearing Defects," and copies of the technical support package were distributed to railroad and rapid transit personnel. Immediate interest was indicated.

A test unit has recently been built by Shaker Research, in Latham, New York. The anticipated production price is in the \$900 to \$1000 range.

Shock/Vibration Monitor: Claims for freight damage cost the nation's railroads about a quarter of a billion dollars annually. With a better knowledge of the actual freight environment, the industry could prevent freight damage and reduce damage claims. The railroads need an inexpensive (~ \$1000), portable, time referenced, three-axis shock/vibration monitor that can sense 0 to 50 g, 0 to 200 cps loads, record essential statistics, and operate unattended for up to eight days. In addition, it must be possible for nontechnical personnel to read out and reset the recorder.

A Technology Survey yielded a NASA-Langley vibration recorder (NASA Tech Brief 71-10126) and an AEC shock/vibration monitor (AEC/NASA Brief UCRL-72748). Each instrument met some of the requirements; together they meet all the requirements. A Market Survey indicated the need for such a unit. A Preliminary Economic Analysis indicated that the unit could be produced for about \$1000--a competitive price. These reports plus design details were given to a Pennsylvania manufacturer who is currently preparing to fabricate a device that combines the AEC design with a design developed at NASA-Langley.

Shatterproof Windows: From the standpoint of maintenance and repair, bus and rapid transit windows are a major concern of operators. Broken windows from rocks thrown at passing buses and rapid transit cars and from road debris represent both a safety hazard and an economic burden. The need for shatterproof, optically clear materials for use in windows has therefore been demonstrated. Although materials are currently available that claim to meet this need none has proven totally acceptable.

A research and development program currently under way at NASA-Ames is involved in the fabrication of shatterproof, fire-safe plastic windows for commercial aircraft. An expected benefit from this program will be the development of a more shatter-resistant plastic window material for bus and rapid transit application.

SOME SELECTED CURRENTLY ACTIVE PROBLEMS

Pavement Surface Measurement: Highway-accident researchers have identified significant relationships between road surface texture characteristics and skid-related accident rates. As a result, the Federal Highway Safety Act of 1966 provided for "pavement design and construction with specific provisions for high skid-resistance qualities" and "resurfacing or other surface treatment...of streets and highways with low skid resistance...." The surface texture of highway pavements must be measured to determine skid potential. The test device (preferably an electronic instrument) should be operable at maximum highway speeds.

Pavement Compressive Strength Measurement: The strength of a given concrete varies with a number of factors, the more important being compressive strength of the cement paste and gradation and strength of the aggregates, the mix proportions, the water-cement ratio, and the curing methods. Several standardized tests have been developed by the American Society for Testing and Materials; however, these tests are limited to individual concrete mix components or to laboratory or job mix samples in an environment differing drastically from the finished pavement.

A rapid, inexpensive, and accurate method is needed to measure the structural strength of the finished pavement.

Electric Vehicle: The Postal Service is considering electric vehicles for mail delivery. Although long-range plans include a fuel cell concept for supplying power, an improved battery would provide a good short-range solution. Currently available lead-acid batteries supply 10 to 15 watt-hr/lb, whereas at least 30 watt-hr/lb are necessary to accelerate from 0 to 45 mph in 45 seconds during transit and from 0 to 10 mph in 3 seconds during mail delivery. As many as 130 stops may be required on one route, 35% on uphill grades. To take full advantage of battery improvements, a more efficient electric motor is also being sought, one requiring little maintenance.

Work is under way at NASA-Lewis to design a high performance battery which in laboratory tests on small cells is achieving very close to 30 watt-hr/lb.

Railcar Component Screening: The Federal Railroad Administration recently proposed its first safety standards for freight cars, to cover correction of such defects as faulty suspension systems, loose wheels, broken axles, and worn couplers. To comply with these standards, the railroads must develop inspection systems to detect bad components. A rapid method of screening railcars is being sought.

Defective Railcar Wheel Detection: Some 100 derailments annually are attributed to the failure of railcar wheels, and the loadings. No routine procedure exists for spotting defective wheels. Any method preferably located at trackside, would have to be sensitive to cracks in the wheel flange, rim, plate, and hub.

For additional information on any of these problem areas, please contact the Team members listed below. If your problem areas differ from those listed here, we invite you to discuss them with us. The TAT's activities are only partially represented here. Interaction on numerous other highway, rail, rapid transit and waterways problems is constantly under way. It is indeed possible that we may have already considered the problem you are facing, and may have uncovered a solution for it. We look forward to hearing from you.

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